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(54) EQUIPMENT FOR ELECTRIC ARC WELDING

(71) We, MESSER GRIESHEIM GMBH, a Company organised under the laws of Germany, of D-6000 Frankfurt/Main, Hanauer Landstrasse 330, Germany, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to an equipment for electric arc welding with a melting-off (i.e. consumable) electrode, the equipment having a current source, an arc voltage adjusting means and a welding current adjusting means.

Where arc welding with a melting electrode is concerned, the rate of wire feed and the output voltage of the welding current source which together produce acceptable welding conditions for the particular electrode material and electrode diameter, can be adjusted within wide limits.

In order in practice to use a single current source for both short-circuiting transfer arc welding as well as for spray arc welding, such current sources have means (chokes, step switches and the like) of varying the pitch of the current-voltage characteristic curve, to make it possible to select one of a plurality of current-voltage curves. Where such current sources are concerned, the welding conditions are dependent not only upon the rate of wire feed and the adjustment of the voltage of the welding current source, but moreover also upon the pre-selected current-voltage characteristic curve. The welder must therefore attune these values to one another by manual adjustment in order to create the desired welding conditions. At what is generally the empirical adjustment of the welding conditions by experiment, the welder must therefore depend on his skill and experience.

The manual adjustment of the welding conditions is difficult particularly in the case of welding with a melting electrode and using the short-circuiting transfer process (gas metal arc welding using short-circuiting transfer), since with this method of material transfer the range of adjustment for achieving optimum welding conditions is far narrower than in the case of spray arc welding in which many droplets of material are transferred from the electrode to the workpiece like a spray of rain, free from short-circuits.

It is already known (German Specification No. 1 440 413), in order to simplify the adjustment of current source and rate of wire feed, to ascertain the available arc voltage and to feed the value ascertained to a wire feed motor as a controlled variable. The rate of wire feed is therefore regulated as a function of the arc voltage.

Particularly in the case of short-circuiting arc welding wherein, by virtue of the short-circuiting transfer, for a given neutral voltage the arc voltage constantly fluctuates, the known control arrangement results in a constant varying of the rate of feed and thus an irregular movement of the electrode wire passed the welding point.

It is furthermore known, for example from DAS 1 515 232 and German Specification No. 1 690 624, on the simplified assumption that the current-voltage characteristic in arc welding can be represented by groups of straight lines and that there is a linear relationship between wire feed and welding current, to vary the rate of wire feed and the arc voltage by means of a positioning element. For this purpose, this positioning element is mechanically connected to the arc voltage and wire feed adjusting means.

In the case of a known apparatus of this type, both the wire feed setting means and also the arc voltage adjustment means have associated potentiometers, both potentiometers being mounted on a common adjusting axis.

By virtue of the pitch of the working characteristic (pitch $\Delta \frac{I}{U}$ less than 1) in the current-voltage diagram, it is necessary in order to vary the welding conditions from one working point to another, to vary the welding voltage and the welding current (rate of wire feed) by definite values, welding current and welding voltage variations being different. As a result, also the control signals for varying these parameters must be different. When the above-described combination of potentiometers is used, it is therefore necessary, upon a rotation of the adjusting axis about a definite distance and corresponding to the variation in working point, that the variation in resistance and the resultant variations in control signals of the two potentiometers should be different. However, this entails a considerable expenditure on adjusting and attuning the two potentiometers. Furthermore, by virtue of the mechanical coupling (adjusting axis to wiper contacts), the susceptibility of such an adjustment means to breakdowns is relatively high and considerable maintenance is necessary.

A further disadvantage of these known arrangements resides in the fact that, without the adjustment of additional elements, the potentiometer combination can only be used for varying working points which lie on a common working characteristic curve having the same pitch.

In the case of a welding job which, for constant protective gas, wire diameter and wire material, requires an adjustment from one working point in the short-circuiting arc range to a working point in the spray arc range, it is necessary by virtue of the different pattern of the spray arc working characteristic curve, to actuate an additional mechanism other than the potentiometers. Where the known welding current sources are concerned, the additional arrangement is provided in the control circuit for the wire feed motor, in other words the welding current adjusting means. However, such an arrangement has the disadvantage that in conjunction with the pre-set static characteristic curve with a falling pattern (3 to 7 V per 100 A), a relatively large non-linear current variation is required in order to achieve a variation in working point. Therefore, where these current sources are concerned, the transfer range between short-circuit arc welding and spray arc welding is relatively great and no welds can be performed with satisfactory results in the upper short-circuit arc range or lower spray arc range.

Furthermore, German Specification No. 2 046 940 has disclosed an apparatus with which the disadvantages of the aforesaid equipment can be avoided in that the welding voltage—as a controlled variable—is fed through a non-linear four-pole circuit to an adjusting means for the wire feed motor.

The object of the present invention is to provide an apparatus with which the welding current and welding voltage can be influenced with extreme ease.

In order to reslove this problem, it is suggested that the welding voltage and welding current adjusting means be electrically connected to a single adjusting element.

According to the invention there is provided an apparatus for electric arc welding using a consumable electrode and having a current source, a welding voltage adjusting means and a welding current adjusting means, in which a single adjustable control element is provided, the electrical output signal of which is supplied to the welding voltage and welding current adjusting means so that the desired welding voltage and current may be obtained.

In an advantageous further development, the adjusting means is a potentiometer provided in a control circuit. For the adjustment of the welding current or welding voltage, only a commercially available potentiometer is necessary, the output from which is connected both the current adjusting and to the voltage adjusting equipment.

When it is desirable to change the working point, it is possible merely by rotating the potentiometer, to vary its output voltage and, via elements (for example resistances or the like) provided in the current or voltage adjusting means, to convert this voltage into signals proportional to the necessary current or voltage change. The definite association of current and voltage mentioned at the outset and dependent upon the inclination of the working characteristic curve, is therefore not achieved already at the setting member but only in the corresponding adjustment means. This has the advantage that the construction of the setting member becomes simpler, together with its manufacture and adjustment; its working life is also prolonged.

In order without actuating further means to permit a change in working point from short-circuit arc to spray arc ranges with one potentiometer, according to an advantageous further development of the invention, the welding voltage adjusting means has a non-linear component which is so designed that the output signal from the voltage adjusting means is non-linear.

As a result of the non-linear component, for example a non-linear amplifier, it is possible with one adjusting element to set any desired working points on a working characteristic curve of varying pitch extending from the lowest short-circuit arc range up to the highest spray arc range. The disposition of the non-linear component in the voltage adjustment means that despite

the non-linear association of welding voltage and welding current (wire feed), the rate of wire feed is varied along a straight line of predetermined pitch. Where a variation in working point is concerned, this has the advantage that the wire feed is continuously increased or diminished with no sudden change in the rate of feed of the wire. Another advantage is that the entire means of controlling the wire feed motor can be made simpler and more accurate.

A further advantage of providing the non-linear component in the voltage adjusting means resides—as experiments have shown—in the fact that a variation in working point can be achieved far more rapidly via a non-linear voltage pattern than via a non-linear variation in wire feed.

The invention will be described in greater detail hereinafter with reference to an example of embodiment, reference being made to and further advantageous features of the invention being brought out with reference to the attached drawings, in which:

Figure 1 is a diagrammatic representation of the equipment for short-circuit and spray arc welding according to the invention;

Figure 2 is a graphic representation of the output signal from the non-linear amplifier according to the invention;

Figure 3 shows a front panel with setting means, used for the apparatus according to Figure 1;

Figure 4 and 5 are graphic views of the current-voltage characteristic curves and of the working curves for various diameters of wire and various types of protective gas.

The equipment according to Figure 1 has a current source 10 with a wire feed device 11 and a welding voltage adjusting means 12 and a welding current adjusting means 13.

The current source 10—preferably a CP current source (one in which the voltage remains substantially constant with a change of current)—consists essentially of a transformer 14, downstream of which there is a rectifier bridge 15 with controllable semiconductors (preferably thyristors) 16.

The outputs 17, 17' of the rectifier bridge 15 are connected to the melting electrode 18 of a diagrammatically shown per se known protective gas welding torch 19 and a workpiece 20. The protective gas torch 19 further communicates with a protective gas supply apparatus 22 through pipes 21.

According to the invention, the welding voltage adjusting means 12 and the welding current adjusting means 13 are connected to a single positioning element 23. The positioning element 23 is preferably constructed as a potentiometer provided in a control circuit 24.

The control circuit 24 consists substantially of a direct current source 25 (shown diagrammatically in Figure 1 as a battery). The voltages at output points 28 and 29 are always equal, but the magnitude of this voltage varies with the potentiometer setting. The output 28 is electrically connected to the welding voltage adjusting means 12 while the output 29 is electrically connected to the welding current adjusting means 13.

Preferably, the voltage adjusting means 12 has a non-linear component, preferably a non-linear amplifier 30, which is so designed that the output signal UA of the adjusting means 12 is non-linear. In Figure 2, such polygon traces are illustrated as a function of the input voltage UE, in fact for different wire diameters (0.8; 1.0; 1.2 and 1.6). Above these polygonal traces, Figure 2 also shows in m/min. the rate of feed appropriate to each wire diameter.

A particularly advantageous and simple construction of the non-linear amplifier 30 is identified by an operational amplifier 31, the input 32 of which is connected to a unit 33, 34, 35, 36 comprising resistances with a parallel-connected resistance diode branch, the diodes being negatively biassed.

Each of the units 33 to 36 is designed for a definite wire diameter and can be selectively connected to the calculating amplifier input 32 via a switching means 37.

Furthermore, the voltage adjusting means has a pre-selector device 38 for adapting the welding voltage to the type of welding gas. In the case of the example of embodiment, the pre-selector device 38 consists of switchable resistances 39, 39' which are disposed in parallel with the operational amplifier from input 32 to 40.

The output 40 of the operational amplifier is connected to three following per se known striking pulse transmitters 41 which communicate with controllable semi-conductors 16 disposed in the current circuit of the welding current source 10.

The welding current adjusting means 13 consists of a differential amplifier 42 which comprises a linear operational amplifier, its output 43 being connected to a striking pulse transmitter 44. The striking pulse transmitter 44 is connected to the controllable semiconductor (thyristor or the like) 47 disposed in the circuit 45 of the electrode feed motor 46. One input 48 of the amplifier 43 is connected to the potentiometer 23 which serves as a rotary speed desired value transmitter, while the other input 49 is connected to a resistor 50 which serves as a rotary speed actual value transmitter.

The striking pulse transmitters 41, 44 used in the welding voltage and welding current setting means 12, 13 respectively are of identical construction and consist of a uni-junction transistor 51, the emitter 52 of which is connected to a resistor 53 and a capacitor 54. The base contact 55 of the uni-junction transistor 51 is connected to the

control electrode 57, 58 of the thyristor 16, 47 via an isolating transformer 56.

The manner in which the equipment according to the invention functions is explained in greater detail with reference to the front panel 59 shown in Figure 3 and relating to the welding current source 10 in conjunction with Figure 1 and the characteristic curves shown in Figures 2, 4 and 5.

In Figure 3, the pre-selector head for the wire diameter ranges 0.8, 1.0, 1.2 and 1.6 mm is designated 60 and the pre-selector switch for the type of gas (protective gas: CO_2 switch at the bottom; protective gas: blended gas comprising Ar, He, O_2 and CO_2 switch at the top) is designated 61. The potentiometer 23 which in most cases is mounted on the protective gas torch 19, on a welding guard or secured by means of a magnet to the workpiece 20 is connected through control lines 23' to the front panel 59. Provided on the scale of the potentiometer 23 are four adjusting ranges (62a, b, c, d), the range 62a being associated with a 0.8 mm electrode wire, the range b being associated with one of 1.0 mm, the range c with one of 1.2 mm and the range of d with one of 1.6 mm. Each of the ranges can be again sub-divided into a short circuiting arc range and a spray arc range. The potentiometer knob is designated 63.

Figures 4 and 5 show various working characteristic curves, the broken lines relating to CO_2 arc welding and the solid lines relating to arc welding with a blended gas as the protective gas. Figures 4 and 5 show that the CO_2 characteristic compared with the blended gas characteristic curves, will require a higher voltage value and that furthermore with increasing wire diameter, the voltage values have to be reduced, subject to the current source strengths remaining constant. These characteristic curves have been in each case plotted with the same electrode material.

For example, if an electrode wire of 1 mm diameter has to be welded under CO_2 (see Figure 5, top graph), then by rotation of the pre-selector knob 60 to the value 1.0, the unit 34 is connected to the operational amplifier 31 and furthermore the pre-selector switch 61 is moved downwards so that the resistors 39 are associated with the operational amplifier 31. The amplification factor of the operational amplifier is now determined solely by the ratio of the resistors 39 to the total resistance of the unit 34. Starting from a potentiometer setting of zero and with a slow rotation in the direction of the arrow P on the scale 62, the following occurs:

By virtue of the negative voltage 70, the diode 71 is negatively biassed via the resistor 72 and is therefore blocked. The amplification factor corresponds to the ratio of the resistor 39 to the resistor 73 (portion 74 of the polygonal trace in Figure 2 or change of the working point from A to B on characteristic curve 1.0-CO_2 in Figure 4).

If rotation of the potentiometer 23 further increases the input voltage UE and if this exceeds the negative bias, the diode 71 becomes conductive. Thus, the resistor 75 and a part of the resistor 72 are connected in parallel with the resistor 73 so that the total resistance of the unit 34 is smaller. The amplification factor therefore becomes greater and a kink (working point zone C) is created in the polygonal trace (portion 76 thereof in Figure 2) as well as in the working characteristic curve. By virtue of this non-linear pattern, it is possible to adjust any desired working point on the working characteristic curve solely by rotating the potentiometer 23. The manner of function of the other unit is correspondingly the same whereby, as in the case of the unit 36, also a plurality—for example two—of diodes of different initial bias may be provided, so that a plurality of kinks are created (see also topmost characteristic curve in Figure 2). In this connection, it should be pointed out that the slight curvature of the current-voltage characteristic curves in Figures 5 and 4 following the kink C are caused by the falling characteristic of the current source and the characteristic curve of the thyristor assembly 15. When welding with a mixed gas as the protective gas, the mains unit function accordingly. Merely by switching the resistor 39 over to a smaller resistance value (resistance 39'), the amplification factor is altered to arrive at lower working voltages.

The output voltages which arise from the non-linear component are slightly (0.1 to 0.2 V) smaller than the values illustrated in Figure 2.

As is also revealed by the characteristic curve which can be achieved with the equipment according to the invention, by virtue of the non-linear control of the welding voltage, the range between the short-circuiting arc range and the spray arc range is small.

Thus it is possible—without welding errors resulting—to switch from the short-circuiting arc range to the long arc range, such as is necessary for example when performing welding work where first the root layer of a weld is made with a short-circuiting arc after which the filling layer is welded with a spray arc.

In the case of the present example of embodiment, the welding voltage adjustment is effected via a rectifier bridge with controllable semi-conductors. It is naturally also possible advantageously to employ the equipment described according to the invention for transduction-controlled current sources in which a controllable semiconductor is provided in the transducer exciter circuit.

Moreover, instead of the biassed diodes, it is possible to provide zener diodes or equivalent components in the units 33-36.

WHAT WE CLAIM IS:—

1. An apparatus for electric arc welding using a consumable electrode and having a current source, a welding voltage adjusting means and a welding current adjusting means, in which a single adjustable control element is provided, the electrical output signal of which is supplied to the welding voltage and welding current adjusting means so that the desired welding voltage and current may be obtained.

2. An apparatus according to claim 1, in which the control element comprises a potentiometer arranged, on adjustment, to provide varying proportions of a reference voltage, the output of the potentiometer being electrically connected both the welding voltage adjusting means and to the welding current adjusting means.

3. An apparatus according to claim 1 or 2, in which the welding voltage adjusting means provides a non-linear output.

4. An apparatus according to claim 3 in which the welding voltage adjusting means comprises a non-linear amplifier.

5. An apparatus according to claim 4 in which the non-linear amplifier comprises an operational amplifier, an input of which is connectable to one of a plurality of non-linear impedances.

6. An apparatus according to claim 5 in which each of the non-linear impedances is designed for a definite wire diameter and is connectable to the operational amplifier through a switching means.

7. An apparatus according to any of claims 4 to 6 in which the welding voltage adjusting means comprises, downstream of the non-linear amplifier, at least one striking pulse transmitter which is connected to a controllable semi-conductor disposed in the welding current source circuit.

8. An apparatus according to any of claims 1 to 7 in which the welding voltage adjusting means comprises a preselector device for adapting the welding voltage characteristic to the type of welding gas employed.

9. An apparatus according to claim 8 in which the preselector device comprises resistors associated with the operational amplifier in feedback relationship therewith.

10. An apparatus according to any of claims 1 to 9, in which the welding current adjusting means comprises an amplifier which is connected to a striking pulse transmitter which is connected to a controllable semiconductor disposed in a circuit for controlling the electrode feed motor.

11. An apparatus for electric arc welding substantially as hereinbefore described with reference to the accompanying drawings.

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1410870 COMPLETE SPECIFICATION

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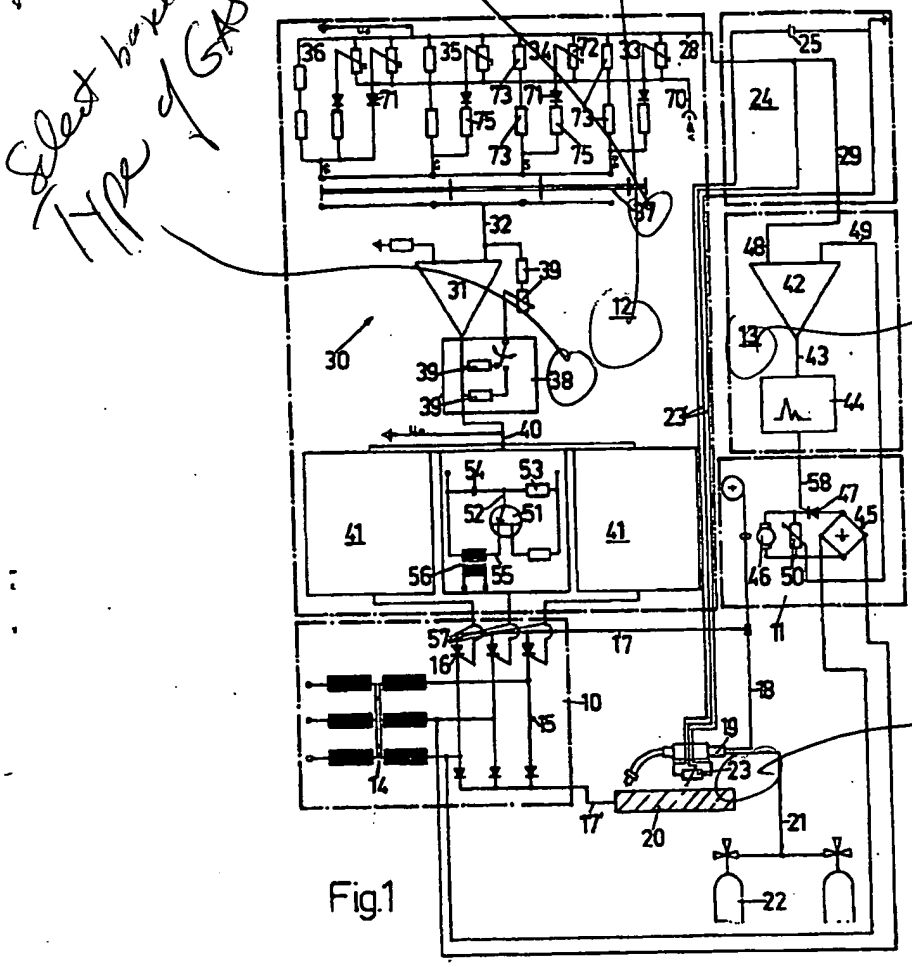

Fig.1

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Sheet 2

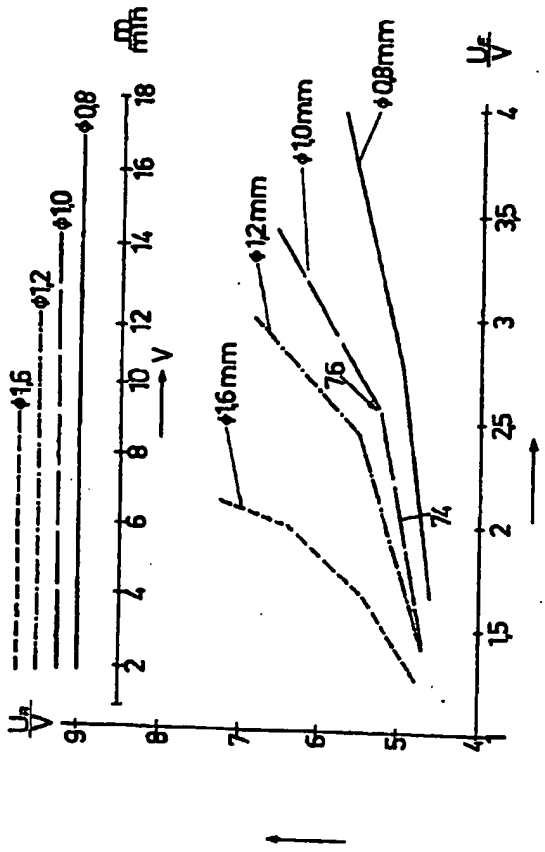

Fig. 2

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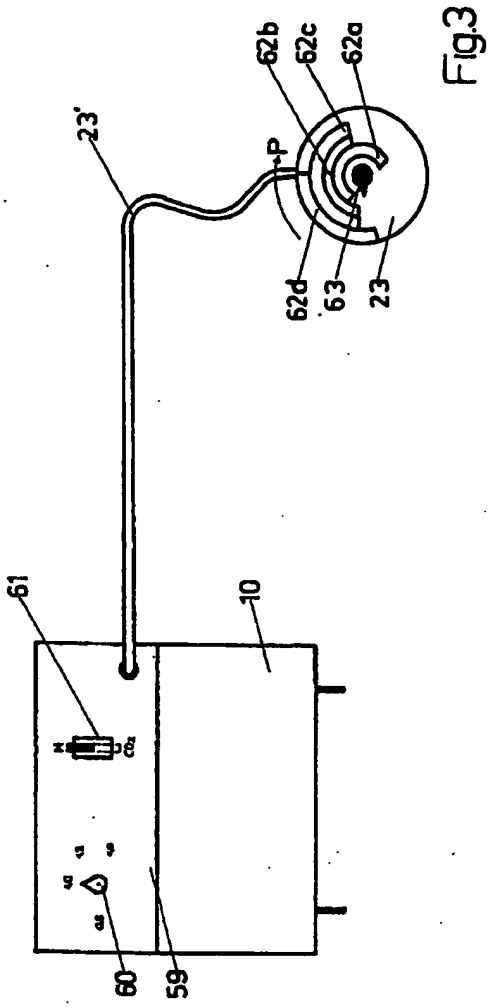
Sheet 3

Fig.3



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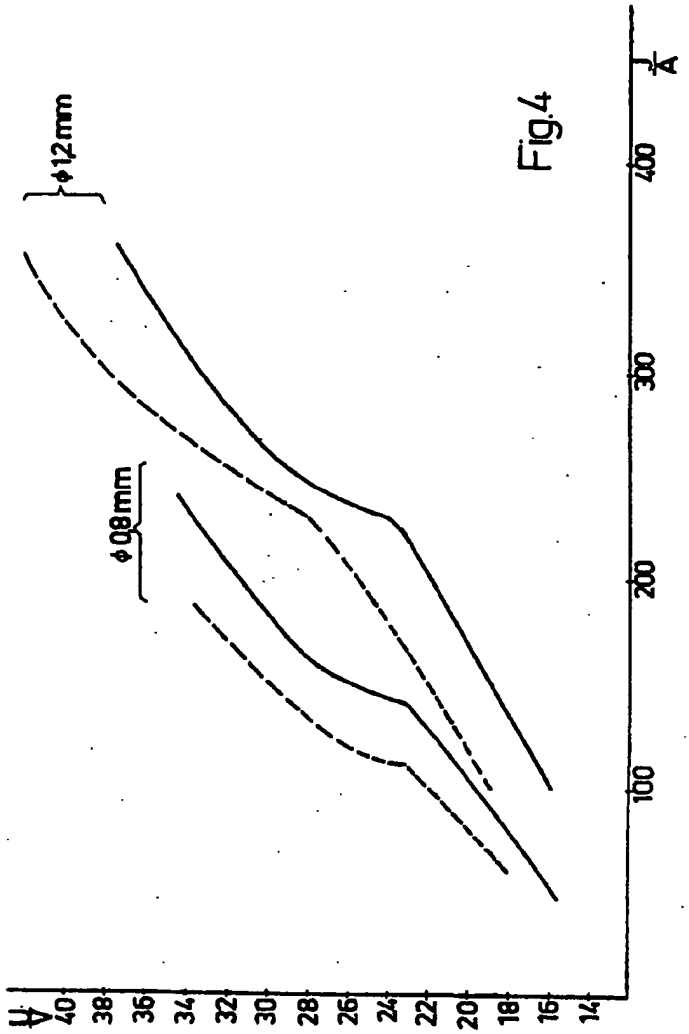

Fig.4

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Fig.5